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The vegetation of ash disposal sites at Hendrina Power Station II: Floristic composition

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An important component of any ecosystem is the species it contains. Species also serves as good indicators of the ecological condition of a system. A list of all species collected during the three-year period was therefore compiled together with their life form spectra. The floristic composition of the ash disposal area at Hendrina Power Station was also compared with the floristic composition of an adjacent natural grassland. A total of 278 species were identified of which 151 occurred on the ash disposal sites and 163 in the natural grassland. Of all the species, 35 occurred in both areas of which most were annual pioneer species. The species composition and life form spectra of the two areas were considerably different. Therophytes were, for example, more abundant on the ash disposal areas. The reconstruction of an ecosystem on ash disposal sites with a species composition similar to that of the natural grassland will require far more financial inputs and habitat amelioration than is presently the situation.

Introduction

Species in an ecosystem forms an important component that can be used as ecological indicators. The total species composition cannot be ignored, especially on disturbed land. Derelict land is characterised by distinct floras due to the habitat differences which exist in such areas (Bradshaw 1983) and the colonisation by uncommon species (Bradshaw and Chadwick 1980) with different life form compositions. Due to present rehabilitation practices only a small number of species establish which therefore leads to an ecosystem of low diversity (Roberts *et al.* 1981). Floras of derelict land are however seldom studied and are therefore relatively unknown. The floristic composition of these sites may however give important information on the ecological and environmental conditions that persists on derelict land. Species of certain families are normally associated with specific soil conditions and can be used as indicators of such conditions (Bradshaw and Chadwick 1980).

The life form spectra of species were used by Down (1973) to determine successional patterns and to describe the vegetation on colliery waste. Down (1973) used life form spectra because basic floristic methods were found to be of limited value since the high variability of early colonisers and ruderal species during early successional stages. The plant community structure on reclaimed non-ferrous metal sites were also investigated by Vangronsveld *et al.* (1996) by comparing the life form spectra and species composition between treated and untreated sites Down (1973). The description of communities based on floristic composition were also difficult in the phytosociological study (Morgenthal *et al.* 2001) because of the artificial nature of communities and the stochastic colonisation patterns of annual forbs.

The first paper which investigated the community structure on ash disposal sites indicated that the natural vegetation of the area are very different from the vegetation established on ash disposal sites (Morgenthal *et al.* 2001). Different treatments and quality of the topsoil (seed bank) and prevailing environmental conditions on ash disposal sites could have an important influence on the community structure of the vegetation (Morgenthal *et al.* 2001).

The aim of this study is to compare the adjacent natural grassland with the ash disposal sites in terms of their floristic composition, γ-diversity and life form spectra. A further aim of the study is to provide a list of all species collected in these two areas during the three-year survey period. Results may give some insight into the floristic characteristics of derelict areas for example ash disposal areas.

Materials and Methods

The study was conducted at one of the power stations of ESKOM near Hendrina, Mpumalanga, South Africa. A general description of the land use, vegetation, climate as well

as a detailed description of rehabilitation practices used and developed plant communities on ash disposal sites at Hendrina Power Station are provided by Morgenthal (2001)

This paper presents floristic data on all species collected during three monthly surveys over a three-year survey period on ash disposal sites (215ha) and an adjacent natural grassland (±3ha). Most species were collected during December 1996, March 1997, September 1997, December 1997 and December 1998. It was attempted to obtain a full floristic account of the vegetation on the ash disposal sites and the natural grassland.

Information on the species life forms according to Raunkiaer (1934), habitat type (natural grassland/ash disposal area) and exotic or indigenous status are included. The species, which were used in the seed mixture of the rehabilitation treatments, are also indicated. Species names are systematically arranged accordance with the Engler system and conform to those listed in Arnold and De Wet (1993) and Retief and Herman (1997) except where otherwise indicated.

The percentage similarity between the total floristic composition of the vegetation of the natural grassland and ash disposal areas was also calculated with Sørensens Coefficient of Similarity (Kent and Coker 1994).

Results

Table 1 presents a summary of most represented families occurring on ash disposal areas and the natural grassland including the number of genera that is represented by each family. Table 2 lists the families that were found in the one area but absent in the other area. An annotated list of all species collected and positively identified during the study period is provided in Table 3.

A total of 278 species were collected on the ash disposal areas and the adjacent natural grassland during the study period (Table 3). Ninety-eight species belonged to the Monocotyledonae of which most were from the family Poaceae (69 species). The remainder of the species (180) belonged to the Dicotyledonae. The Dicotyledonae families that were the best represented were Asteraceae (57 species) and Fabaceae (30 species), of which most species belonged to the subfamily Papilionoideae (Table 3).

Difference in γ-diversity (overall) of ash disposal areas and the natural grassland studied

The Sørensens Index indicates a 22.6% similarity between the two areas. Thirty-six species occur in both areas including the forbs *Tagetes minuta*, *Schkuhria pinnata*, *Helichrysum callicomum*, *Pseudognaphalium undulatum*, *Pseudognaphalium luteo-album*, *Conyza bonariensis*, *Conyza podocephala*, *Nidorella anomala*, *Lobelia flaccida*, *Wahlenbergia undulata*, *Kohautia amatymbica*, *Verbena bonariensis*, *Walafrida densiflora*, *Sebaea grandis*, *Hibiscus microcarpus*, *Sida dregei*, *Euphorbia striata*, *Pelargonium luridum*, *Zornia milneana*, *Tephrosia capensis*, *Chamaecrista biensis*, *Delosperma herbeum*, *Commelina africana*, *Bulbostylis humilis* and *Kyllinga erecta*. Grasses which were collected in both areas are *Cynodon dactylon*, *Eragrostis plana*, *Eragrostis curvula*, *Eragrostis chloromelas*, *Eragrostis capensis*, *Sporobolus africana*, *Setaria sphacelata* var. *torta*, *Themeda triandra*, *Heteropogon contortus* *Cymbopogon excavatus* and *Hyparrhenia hirta*. A total of 151 species was collected on the ash disposal sites and 163 species in the natural grassland.

Table 1: Families with two or more genera occurring on rehabilitated ash disposal sites or the natural grassland at Hendrina Power Station and the number of genera represented

Families	Ash disposal sites	Natural grasslands
Poaceae	31	24
Asteraceae	19	18
Fabaceae (subfamily: Papilionoideae)	9	11
Cyperaceae	3	3
Malvaceae	2	2
Rubiaceae	1	5
Euphorbiaceae	1	3
Asclepiadaceae	1	3
Geraniaceae	1	2
Convolvulaceae	1	2
Gentianaceae	1	2
Lobeliaceae	1	2
Scrophulariaceae	4	
Amaranthaceae	3	
Solanaceae	3	
Polygonaceae	2	
Chenopodiaceae	2	
Brassicaceae	2	
Onagraceae	2	
Liliaceae		8
Acanthaceae		4
Apiaceae		2
Lamiaceae		2

Table 2: Families found in the one study area, but did not occur in the other area at Hendrina Power Station

Families only found on the ash disposal sites	Families only found in natural grassland
Cannaceae	Juncaceae
Polygonaceae	Liliaceae
Chenopodiaceae	Orchidaceae
Amaranthaceae	Santalaceae
Nyctaginaceae	Illecebraceae
Aizoaceae	Caryophyllaceae
Portulacaceae	Crassulaceae
Brassicaceae	Rhamnaceae
Capparaceae	Sterculiaceae
Polygalaceae	Thymelaeaceae
Tilliaceae	Apiaceae
Onagraceae	Periplocaceae
Solanaceae	Acanthaceae
Cucurbitaceae	Lamiaceae
Schrophulariaceae	Plantaginaceae
	Dipsacaceae

Difference in the life form spectra between ash disposal areas and the natural grassland

Figure 1 indicates the difference in life form composition according to Raunkiaer (1934). The most represented life form in all the areas was the hemicryptophytes (Figure 1). Many of the forbs with perennial rootstocks belong to the proto-hemicryptophytes, which is characterised by the elongated aerial shoots and the largest leaves in the middle portion of the shoots. Many of the species that have a hemicryptophytic life form occur in the natural grassland, namely *Gnidia caffra*, *Acalypha angustata*, *Schistostephium crataegifolium* and most of the species of the family Fabaceae. All perennial species of the Poaceae and most perennial species of the Asteraceae (*Hypochaeris radicata*, *Berkheya setifera*, *Helichrysum nudifolium* and *Senecio coronatus*) have, however, a rosette life form. A hemicryptophytic life form with leaves in a rosette at the base of the plant seems to be an important survival strategy of plant species in the study area because of the large number of species with this type of strategy.

The major difference in life form spectra between natural grasslands and the ash disposal areas is the large number of therophytes on the ash disposal areas. The number of therophytes on the ash disposal sites was similar to the number of hemicryptophytes on these sites. Examples of species which are therophytes are the species from the family Asteraceae, for example *Bidens bipinnata*, *Schkuhria pinnata* and *Conyza bonariensis;* species from the family Chenopodiaceae, for example *Chenopodium album* and from the family Poaceae, for example *Eleusine coracana* subsp. *africana*, *Eragrostis tef* and *Setaria pallide-fusca*. The second most important life form in the natural grassland is species with a cryptophytic life form and is considerably lower than the number of species with a hemicryptophytic life form.

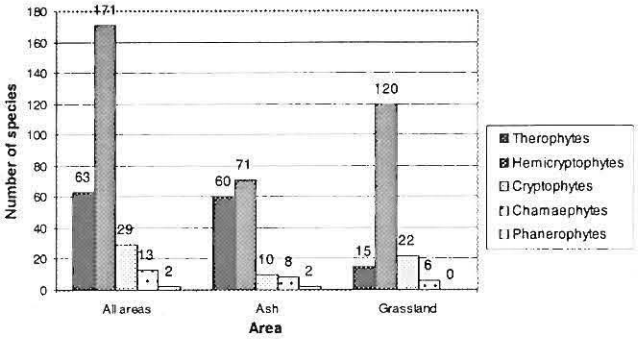

Figure 1: Life form spectra of plant species for all sites (All areas) investigated, ash disposal sites (ash) and an adjacent natural grassland (Grassland) at Hendrina Power Station

Comparison of families occurring on ash disposal sites and the natural grassland

The families Poaceae, Asteraceae and Fabaceae (Papilionoideae) were the most represented families according to the number of genera in both the natural grassland and the ash disposal sites. These three families also contain the most species in comparison to the other families (Table 1). The family Poaceae was represented by a total of 44 species on the ash disposal sites and 34 species in the natural grassland. Thirty species that occurred on ash disposal areas, and 34 species from the natural grassland belonged to the family Asteraceae. The families which were represented by a smaller number of genera were, however, considerably different between the two areas. Families that were represented in both areas are for example the Cyperaceae and Malvaceae (Table 1). Families present in only one of either the natural grasslands or the ash disposal sites are listed in Table 2. Although a total of 12 species, from the family Liliaceae, occurred in the natural grassland, species from this family were absent on the ash disposal sites. Families with species typically occurring in saline and ruderal conditions (for example Chenopodiaceae, Amaranthaceae, Aizoaceae and Brassicaceae) were not represented in the natural grassland (Table 2).

Discussion

Although both areas studied have only a few perennial grass species, which occur dominantly, a large number of other species which occur less frequently, were also collected. A characteristic of the vegetation of both areas is the large number of species that belong to the families Poaceae, Asteraceae and Fabaceae.

The two areas were, however, floristically totally different. The species that occurred in both areas were opportunistic annual species with a therophytic life form. The number of hemicryptophytic grasses and particularly hemicryptophytic forbs were low in both areas. Although alpha diversity for the two areas was dissimilar, gamma diversity was very similar. It must be noted that the surface area of the ash disposal

Table 3: Checklist of all species encountered on ash disposal areas (ash) and an adjacent natural grassland (grass) at Hendrina Power Station from 1997 to 1999

	Species	Ash	Grass	Life form
MONOCOTYLEDONAE				
Poaceae				
9900170	***Urelytrum* Hack.**			
	U. agropyroides (Hack.) Hack. (409)		x	Hemicryp
9900280	***Elionurus* Kunth ex Willd.**			
	E. muticus (Spreng.) Kunth		x	Hemicryp
9900370	***Imperata* Cirillo**			
	I. cylindrica (L.) Raeusch.	x		Hemicryp
9900710	***Andropogon* L.**			
	A. eucomus Nees (396)	x		Hemicryp
	A. schirensis A.Rich.		x	Hemicryp
9900720	***Cymbopogon* Spreng.**			
	C. excavatus (Hochst.) Stapf ex Burtt Davy	x	x	Hemicryp
9900730	***Hyparrhenia* Fourn.**			
	H. hirta (L.) Stapf*	x	x	Hemicryp
	H. tamba (Steud.) Stapf	x		Hemicryp
9900780	***Trachypogon* Nees**			
	T. spicatus (L.f.) Kuntze [2] (253)		x	Hemicryp
9900800	***Heteropogon* Pers.**			
	H. contortus (L.) Roem. & Schult.)*	x	x	Hemicryp
9900810	***Diheteropogon* (Hack.) Stapf**			
	D. amplectens (Nees) Clayton		x	Hemicryp
9900830	***Themeda* Forssk.**			
	T. triandra Forssk.*	x	x	Hemicryp
9900890	***Digitaria* Haller**			
	D. eriantha Steud.*	x		Hemicryp
	D. monodactyla (Nees) Stapf		x	Hemicryp
	D. ternata (A. Rich.) Stapf [2] (295)		x	Hemicryp
	D. tricholaenoides Stapf (419)		x	Hemicryp
9900940	***Alloteropsis* Presl**			
	A. semialata (R. Br.) Hitchc. subsp. *semialata* (404)		x	Hemicryp
9901040	***Brachiaria* (Trin.) Griseb.**			
	B. serrata (Thunb.) Stapf		x	Hemicryp
9901070	***Paspalum L.***			
	P. dilatatum Poir.	x		Hemicryp
	P. scrobiculatum L. [2] (303)	x		Hemicryp
9901100	***Urochloa* Beauv.**			
	U. mosambicensis (Hack.) Dandy (343)	x		Cham
9901160	***Panicum* L.**			
	P . coloratum L. var. *coloratum* (426)	x		Ther
	P. maximum Jacq.	x		Hemicryp
	P. natalensis Hochst.		x	Hemicryp
9901280	***Setaria* Beauv.**			
	S pallide-fusca (Schumach.) Stapf & C.E. Hubb.	x		Ther
	S sphacelata (Schumach.) Moss var *torta* (Stapf) Clayton	x	x	Hemicryp
	Setaria sp. *cf nigrirostris* (Nees) Dur. & Schinz		x	Hemicryp
9901340	***Melines* Beauv.**			
	M. repens (Willd.) Zizka subsp. *repens*	x		Ther
9901390	***Pennisetum* Rich**			
	P. clandestinum Chiov.#*	x		Hemicryp
9901400	***Cenchrus L.***			
	C. ciliaris L.*	x		Hemicryp
9901740	***Tristachya* Nees**			
	T. leucothrix Nees		x	Hemicryp
9901950	***Avena* L.**			
	A. fatua L.# (397)	x		Ther
9901970	***Helictotrichon* Schult.**			
	H. turgidulum (Stapf) Schweick.[2] (293)		x	Hemicryp
9902110	***Cortaderia* Stapf.**			
	C. jubata (Lem.) Stapf#	x		Hemicryp

Table 3 cont.

	Species	Ash	Grass	Life form
9902130	***Arundo* L.**			
	A. donax L.#	x		Cham
9902430	***Agrostis L.***			
	A.eriantha Hack. var *eriantha* (398)	x		Hemicryp
	A. lachnantha Nees var. *lachnantha* [2] (296)	x		Hemicryp
9902460	***Calamagrostis* (Adanson)**			
	Calamagrostis sp.#[2] (309)	x		Hemicryp
9902620	***Aristida* L.**			
	A. aequiglumis Hack. [2] (251)		x	Hemicryp
	A. congesta Roem. & Schult. subsp. *congesta*	x		Hemicryp
9902830	***Sporobolus* R. Br.**			
	S. africanus (Poir.) Robyns & Tournay	x	x	Hemicryp
9902860	***Eragrostis* Wolf**			
	E. barbinodis Hack.		x	Hemicryp
	E. capensis (Thunb.) Trin. (386)	x	x	Hemicryp
	E. chloromelas Steud.*	x	x	Hemicryp
	E. curvula (Schrad.) Nees*[2] (256) (257)	x	x	Hemicryp
	E. echinochloidea Stapf* (382)	x		Hemicryp
	E. gummiflua Nees		x	Hemicryp
	E. lehmanniana Nees var. *lehmanniana**	x		Hemicryp
	E. nindensis Ficalho & Hiern		x	Hemicryp
	E. plana Nees	x	x	Hemicryp
	E. racemosa (Thunb.) Steud.		x	Hemicryp
	E. tef (Zucc.) Trotter#* (344)	x		Ther
	E. trichophora Coss. & T. Durand	x		Hemicryp
	Eragrostis sp. (294)	x		Hemicryp
9902940	***Microchloa* R. Br.**			
	M. caffra Nees		x	Hemicryp
9902960	***Cynodon* Rich.**			
	C. dactylon (L.) Pers.*	x	x	Cryp
9902980	***Harpochloa* Kunth**			
	H. falx (L.f.) Kunze (399)		x	Hemicryp
9903010	***Chloris* Swartz.**			
	C. gayana Kunth#*	x		Hemicryp
	C. virgata Sw.*	x		Ther
9903310	***Eleusine* Gaetn.**			
	E. coracana (L.) Gaertn. subsp. *africana* (Kenn.- O' Byrne) (371)	x		Ther
9903320	***Dactyloctenium* Willd.**			
	D. aegyptium (L.) Willd. (346)	x		Ther
9903340	***Pogonarthria* Stapf**			
	P. squarrosa (Roem. & Schult.) Pilg.*	x		Hemicryp
9903442	***Bewsia* Goossens**			
	B. biflora (Hack.) Gooss. (418) (315)		x	Hemicryp
9903500	***Triraphis* R. Br.**			
	T. andropogonoides (Steud.) Phill.		x	Hemicryp
9903530	***Trichoneura* Anderss.**			
	T. grandiglumis (Nees) Ekman var. *grandiglumis*		x	Hemicryp
9903570	***Enneapogon* Beauv.**			
	E. cenchroides (Roem. & Schult.) C. E. Hubb.*	x		Ther
9903710	***Fingerhuthia* Nees**			
	F. africana Lehm.*	x		Hemicryp
9904280	***Bromus* L.**			
	B. catharticus Vahl.# (353)	x		Ther
	***Zea* L.**			
	Z. mays L. #	x		Ther
Cyperaceae				
459000	***Cyperus* L.**			
	C. esculentus L. (419)	x		Cryp
	C. obtusiflorus Vahl var. *obtusiflorus (300)* (373)		x	Cryp
	C. usitatus Burch. var. *usitatus*[2] (250)	x		Cryp
462000	***Kyllinga* Rottb.**			
	K. erecta Schumach. [2] (301)	x	x	Cryp
471010	***Bulbostylis* Kunth**			
	B. humilis (Kunth) C.B. Clarke[1] (410)	x	x	Ther

Table 3 cont.

	Species	Ash	Grass	Life form
Commelinaceae				
896000	***Commelina* L.**			
	C. africana L. var. *africana*	x	x	Hemicryp
	C. benghalensis L.	x		Ther
Juncaceae				
936000	***Juncus* L.**			
	J. dregeanus Kunth [2] (302)		x	Hemicryp
Lliliaceae				
989000	***Anthericum* L.**			
	A. calyptrocarpum Baker (364)		x	Cryp
	A. cooperi Baker (366)		x	Cryp
	A. fasciculatum Baker (365)		x	Cryp
1026000	***Aloe* L.**			
	A. ecklonis Sam-Dyck (390)		x	Hemicryp
1029010	***Chortolirion* A. Berger[1]**			
	C. angolense (Baker) A. Berger (389)		x	Cryp
1080000	***Urginea* Steinh.**			
	U. multisetosa Baker (319)		x	Cryp
1084000	***Dipcadi* Medik.**			
	D. marlothii Engl.		x	Cryp
	D viride (L.) Moench (374)		x	Cryp
1088000	***Eucomis* L' Hérit**			
	E. autumnalis (Mill.) Chitt.		x	Cryp
1089000	***Ornithogalum* L.**			
	O. tenuifolium Delaroche subsp. *tenuifolium* [2] (313)		x	Cryp
1090010	***Ledebouria* Roth.**			
	L. inquinata (C. A. Sm.) Jessop [2] (292)		x	Cryp
	L. ovatifolia (Baker) Jessop		x	Cryp
Amaryllidaceae				
1189000	***Crinum* L.**			
	C. bulbispermum (Burm. *f.*) Milne-Redh. & Schweick	x		Cryp
Hypoxidaceae				
1230000	***Hypoxis* L.**			
	H. acuminata Baker		x	Cryp
	H. angustifolia Lam. var. *angustifolia* (318)		x	Cryp
	H. argentea Harv. ex Baker var. *argentea* (356)		x	Cryp
	H. rigidula Baker var. *rigidula* (332) (402)		x	Cryp
Iridaceae				
1311000	***Gladiolus* L.**			
	G. crassifolius Bak. (362)		x	Cryp
	Gladiolus sp.#	x		Cryp
Cannaceae				
1363000	***Canna* L.**			
	C. indica L..#	x		Cryp
Orchidaceae				
1422000	***Habenaria* Willd.**			
	H. epipactidea Richb. F. (378)		x	Cryp
DICOTYLEDONAE				
Santalaceae				
2118000	***Thesium* L.**			
	T. costatum A.W. Hill var. *paniculatum* N.E. Br. [2] (252)		x	Cham
Polygonaceae				
2195000	***Rumex L.***			
	Rumex sp. *cf. lanceolatus* Thumb.	x		Cham
2201030	***Persicaria* Mill.**			
	P. lapathifolia (L.) S.F. Gray	x		Ther
Chenopodiaceae				
2223000	***Chenopodium* L.**			
	C. album L.# (381)	x		Ther
	C. multifidum L.# (387) (388)	x		Ther
2269000	***Salsola* L.**			
	S. kali L. (341)	x		Ther

Table 3 cont.

	Species	Ash	Grass	Life form
Amaranthaceae				
2299000	***Amaranthus* L.**			
	A. hybridus L. # (377)	x		Ther
2330010	***Guilleminea* Kunth**			
	G. densa (Willd.) Moq.#	x		Hemicryp
2338000	***Gomphrena* L.**			
	G. celosioides Mart. #	x		Hemicryp
Nyctaginaceae				
2347000	***Mirabilis* L.**			
	M. jalapa L.#	x		Hemicryp
Aizoaceae				
2376000	***Limeum* L.**			
	L. pauciflorum Moq.	x		Hemicryp
	L. viscosum (Gay) Fenzl	x		Ther
Mesembryanthemaceae				
2405033	***Delosperma* N.E. Br.**			
	D. herbeum (N.E. Br.) N.E.Br. (338)	x	x	Cham
Portulacaceae				
2421000	***Portulaca* L.**			
	P.kermesina N.E. Br	x		Ther
	P. oleracea L.	x		Ther
Caryophyliaceae				
2450000	***Spergularia* (Pers.) J. & C. Presl**			
	S. media (L.) C. Presl ex Griseb.# [2] (245)	x		Cham
Illecebraceae				
2467000	***Pollichia* Aiton**			
	P. campestris Aiton		x	Hemicryp
Caryophyllaceae				
2502000	***Dianthus* L.**			
	D. mooiensis F.N. Williams		x	Hemicryp
Brassicaceae				
2883000	***Lepidium* L.**			
	L. bonariense L.#	x		Ther
2917000	***Sisymbrium* L.**			
	S. thellungii O.E. Schulz (391)	x		Ther
Capparaceae				
3082000	***Cleome* L.**			
	C. monophyla L. (408)	x		Ther
Crassulaceae				
3168000	***Crassula* L.**			
	C. capitella Thunb.		x	Hemicryp
Fabaceae				
Mimosoidea				
3446000	***Acacia* Mill.**			
	A. mearnsii De Willd#	x		Phan
	Acacia sp. *cf*. *gerrardii* Benth var. *gerrardii* (352)	x		Cham
3467000	***Elephantorrhiza* Benth.**			
	E. elephantina (Burch.) Skeels		x	Hemicryp
Caesalpiniodea				
3536010	***Chamaecrista* Moench**			
	C. biensis (Steyaert) Lock [2] (255)	x	x	Ther
Papilionoidea				
3657000	***Lotononis* (D.C.) Eckl. & Zeyh.**			
	L. calycina (E.Mey.) Benth. (320)		x	Ther
	L. foliosa Bolus		x	Hemicryp
3657010	***Pearsonia* Dummer**			
	P. cajanifolia (Harv.) Polhill subsp. *cajanifolia* [2] (244)		x	Hemicryp
3665000	***Melolobium* Eckl. & Zeyh.**			
	M. burchelli N.E. Br. [2] (240)		x	Hemicryp
	M. wilmsii Harms [2] (237)		x	Hemicryp

Table 3 cont.

	Species	Ash	Grass	Life form
3669000	***Crotalaria* L.**			
	C. shinzii Baker f.[2] (297)	x		Ther
3673000	***Argyrolobium* Eckl. & Zeyh.**			
	A. lotoides Harv.[2] (233)		x	Hemicryp
3689000	***Melilotis* Mill.**			
	M. alba Desr. # (355)	x		Ther
3702000	***Indigofera L.***			
	I. atrata N.E. Br. [2] (238)		x	Hemicryp
	I. filipes Benth. ex Harv. [2] (232)	x		Hemicryp
	I. hilaris Eckl & Zeyh. [2] (239)	x		Hemicryp
	I. torulosa E. Mey var. *angustiloba* (Baker f.) J.B. Gillett [2] (235)		x	Hemicryp
3718000	***Tephrosia* Pers.**			
	T. capensis (Jacq.) Pers. var. *capensis* [2] (230) (241) (242)	x	x	Hemicryp
	T. elongata E. Mey. var. *elongata* [2] (254)		x	Hemicryp
	T. polystachya E. Mey. var. *latifolia* Harv. [2] (231)	x		Hemicryp
3802000	***Stylosanthes* Sw.**			
	S. fruticosa (Retz.) Alston [2] (236)	x		Hemicryp
3804000	***Zornia* J. F. Gmel.**			
	Z. milneana Mohlenbr. (336)	x	x	Hemicryp
3820000	***Lespedeza* Michx**			
	L. cuneata (Dum. Cours.) G. Don# [2] (234)	x		Hemicryp
3897000	***Rhynchosia* Lour.**			
	R. minina (L.) DC. var. *prostrata* (Harv.) Meikle [2] (310)	x		Hemicryp
	R. totta (Thunb.) D.C. var. *totta* (314)		x	Hemicryp
2898000	***Eriosema* (DC.) G. Don**			
	E. burkei Benth. (414)		x	Hemicryp
	E. salignum E. Mey. (407)		x	Hemicryp
3905000	***Vigna* Savi**			
	V. oblongifolia A. Rich. var. *parviflora* (Baker) Verdc. [2] (291)		x	Hemicryp
	V. unguiculata (L.) Walp. subsp. *stenophylla* (Harv.) Maréchal *et al.* [2] (308)	x		Hemicryp
	V. vexillata (L.) A. Rich. var. *vexillata* (324)	x		Hemicryp
3910000	***Dolichos* L.**			
	D. sericeus E. Mey. subsp. *sericeus* [2] (311)		x	Hemicryp
Geraniaceae				
3925000	***Monsonia* L.**			
	M. attenuata Harv. (375)		x	Hemicryp
3928000	***Pelargonium* L'Hér**			
	P. luridum (Andr.) Sweet (337)	x	x	Cryp
	P. minimum (Cav.) Willd	x		Hemicryp
Oxalidaceae				
3936000	***Oxalis* L.**			
	O. depressa Eckl. & Zeyh. (392)	x		Cryp
	O. latifolia Humb., Bonpl. & Kunth #	x		Cryp
	O. obliquifolia Steud. ex Rich. (364)	x		Cryp
Polygalaceae				
4273000	***Polygala* L.**			
	P. hottentotta Presl	x		Hemicryp
Euphorbiaceae				
4407000	***Acalypha* L.**			
	A. angustata Sond. var *glabra* Sond. (425)		x	Hemicryp
4498000	***Euphorbia* L.**			
	E. clavaroides Boiss. var. *truncata* (N.E. Br.) White, Dyer & Sloane		x	Hemicryp
	E. striata Thunb. var. *striata* (395)	x	x	Hemicryp
4498000	***Chamaesyce* S. F. Gray**			
	C. inaequilatera (Sond.) Sojak		x	Ther
Rhamnaceae				
4861000	***Ziziphus* Mill.**			
	Z. zeyheriana Sond.		x	Cham
Tilliaceae				
4953000	***Corchorus* L.**			
	C. confusus Wild	x		Hemicryp

Table 3 cont.

	Species	Ash	Grass	Life form
Malvaceae				
4998000	***Sida L.***			
	S. dregei Burtt Davy	x	x	Cham
5013000	***Hibiscus L.***			
	H.aethiopicus L. var *ovatus* Harv.		x	Hemicryp
	H. microcarpus Garcke	x	x	Ther
	H. trionum L.	x		Ther
Sterculiaceae				
5056000	***Hermannia* L**			
	H. depressa N.E. Br.		x	Hemicryp
	H. transvaalensis Schinz. (383)		x	Hemicryp
Tamaricaceae				
5239000	***Tamarix* L.**			
	Tamarix ramosissima Ledeb. #	x		Phan
Thymelaeceae				
5435000	***Gnidia* L**			
	G. caffra (Meisn.) Gilg (339)		x	Hemicryp
	G. kraussiana Meisn. var *kraussiana* (340)		x	Hemicryp
Onagraceae				
5795000	***Epilobium* L.**			
	E. salignum Hausskn (405)	x		Hemicryp
5804000	***Oenothera* L.**			
	O. indecora Cambess. subsp. *bonariensis* W. Dietr.# (334)	x		Ther
	O. laciniata Hill# (379) (327)	x		Ther
	O. tetraptera Cav.#	x		Ther
Apiaceae				
6004010	***Ciclospermum* Lag.**			
	C. leptophyllum (Pers.) Eichler# (325)		x	Ther
6116000	***Peucedanum* L.**			
	P. magalismontanum Sond. (411)		x	Hemicryp
Gentianaceae				
6481000	***Sebaea* Soland. Ex R. Br.**			
	S. grandis (E. Mey.) Steud. (359)	x	x	Ther
	S. leiostyla Gilg (347)		x	Hemicryp
6503000	***Chironia* L.**			
	C. purpurascens (E. Mey.) Benth. *f.* subsp. *humilis* (Gilg) I. Verd. (329)		x	Hemicryp
Periplocaceae				
6747000	***Raphionacme* Harv.**			
	R. hirsuta (E. Mey.) R.A. Dyer ex E. Phillips (350)		x	Hemicryp
Asclepiadaceae				
6778010	***Aspidoglossum* E. Mey.**			
	A. biflorum E. Mey. [2] (299)		x	Hemicryp
6787010	***Pachycarpus* E. Mey.**			
	Pachycarpus sp.		x	Hemicryp
6791000	**Asclepias L.**			
	A.stellifera Schltr. (335)		x	Hemicryp
	A. fruticosa L.	x		Cham
Convolvulaceae				
7003000	***Ipomoea* L.**			
	I. bathycolpos Hallier f. var. *bathycolpos* (361)		x	Hemicryp
	I. crassipes Hook.		x	Hemicryp
	I. ommaneyi Rendle (421)		x	Hemicryp
	I. purpurea (L.) Roth #	x		Hemicryp
7008010	***Turbina* Rafin.**			
	T. oblongata (E. Mey. ex Choisy) A. Meeuse (358)		x	Hemicryp
Verbenaceae				
7138000	***Verbena* L.**			
	V. bonariensis L.#	x	x	Hemicryp
	V. tenuisecta Briq.#	x		Hemicryp
Lamiaceae				
7236000	***Acrotome* Benth**			
	A hispida Benth. (333)		x	Hemicryp
7366010	***Becium* Lindl.**			
	B. obovatum (E. Mey. ex Benth) N. E. Br. subsp. *obovatum* var. *obovatum (349)*		x	Hemicryp

Table 3 cont.

	Species	Ash	Grass	Life form
Solanaceae				
7401000	***Physalis* L.**			
	P. viscosa L.#	x		Ther
7407000	***Solanum* L.**			
	S. nigrum L.# (330)	x		Ther
7415000	***Datura* L.**			
	D. stramonium L.#	x		Ther
Scrophulariaceae				
7460000	***Verbascum* L.**			
	Verbascum sp. *cf. tapsus* L. (316) #	x		Ther
7476000	***Nemesia Vent.***			
	N. fruticans (Thunb.) Benth. (326)	x		Ther
7519000	**Sutera Roth**			
	Sutera sp *cf. caerulea* (L.f.) Hiern (368)	x		Hemicryp
Selaginaceae				
7568010	***Walafrida* E. Mey.**			
	W. densiflora (Rolfe) Rolfe	x	x	Hemicryp
Scrophulariaceae				
7597010	***Alectra* Thunb.**			
	A. sessiliflora (Vahl) Kuntze [2] (258)	x		Hemicryp
7625000	***Striga* Lour.**			
	S. bilabiata (Thunb.) Kuntze (412)		x	Hemicryp
	S. elegans Benth.		x	Hemicryp
Acanathaceae				
7941000	***Chaetacanthus* Nees**			
	C. costatus Nees		x	Hemicryp
7972000	***Crabbea* Harv.**			
	C. acaulis N.E. Br.		x	Hemicryp
	C. angustifolia Nees (348)		x	Hemicryp
7980000	***Blepharis* Juss.**			
	B. innocua C.B. Clarke var. *innocua* [2] (249)		x	Hemicryp
8094000	***Justicia* L.**			
	J. anagalloides (Nees) T. Anderson [2] (307)		x	Hemicryp
Plantaginaceae				
8116000	***Plantago* L.**			
	P. virginica L.# (321)		x	Ther
Rubiaceae				
8136000	***Kohautia* Cham. Schlechtd.**			
	K. amatymbica Eckl.& Zeyh.	x	x	Hemicryp
8348000	***Pentanisia* Harv.**			
	P. angustifolia (Hochst.) Hochst. (403)		x	Hemicryp
8351020	***Pygmaeothamnus* Robyns**			
	P. zeyheri (Sond.) Robyns var. *rogersii* Robyns		x	Hemicryp
8438000	***Anthospermum* L.**			
	A. rigidum Eckl. & Zeyh. subsp. *pumilum* (Sond.) Puff (317)		x	Hemicryp
8464000	***Richardia L.***			
	R. brasiliensis Gomes #		x	Hemicryp
Cucurbitaceae				
8599000	***Cucumis* L.**			
	C. zeyheri Sond. (345)	x		Hemicryp
Dipsacaceae				
8546000	***Scabiosa* L.**			
	S. columbaria L. (428)		x	Hemicryp
Campanulaceae				
8668000	***Wahlenbergia* Schrad & Roth**			
	W. undulata (L.f.) A. DC. (360)	x	x	Hemicryp
Lobeliaceae				
8694000	***Lobelia* L.**			
	L. flaccida (Presl) A. D.C. subsp. *flaccida* [2] (248)	x	x	Ther
8695000	***Monopsis* Salisb.**			
	M. decipiens (Sond.) Thulin (323)		x	Hemicryp

Table 3 cont.

	Species	Ash	Grass	Life form
Asteraceae				
8751000	***Vernonia* Schreb.**			
	V. galpinii Klatt (304)		x	Hemicryp
	V. oligocephala (DC.) Sch. Bip. ex Walp.		x	Hemicryp
8900000	***Aster* L.**			
	A. squamatus (spreng.) Hieron.# (312)	x		Ther
8919000	***Felicia* Cass.**			
	Felicia sp. *cf. fascicularis* D.C.		x	Cham
	F. muricata (Thunb.) Nees	x		Cham
8925000	***Nidorella* Cass.**			
	N. anomala Steetz.	x	x	Ther
8926000	***Conyza* Less.**			
	C. bonariensis (L.) Cronquist#	x	x	Ther
	C. canadensis (L.) Cronquist#	x		Ther
	C. podocephala DC.	x	x	Hemicryp
8992000	***Gnaphalium* L.**			
	G. pensylvanicum Willd.# (357)	x		Ther
8992050	***Pseudognaphalium* Kirp.**			
	P. luteo-album (D.C.) Hilliard & B.L.Burtt	x	x	Ther
	P. undulatum (L.) Hilliard & B.L. Burtl	x	x	Ther
9006000	***Helichrysum* Mill.**			
	H. aureonitens Sch. Bip. (424)		x	Hemicryp
	H. caespititium (DC.) Harv. (384)	x		Hemicryp
	H. callicomum Harv. [2] (259) (322)	x	x	Hemicryp
	H. cephaloideum DC.		x	Hemicryp
	H. coriaceum Harv. (422) (394)		x	Hemicryp
	H. nudifolium (L.) Less. (415)		x	Hemicryp
	H. oreuphium Klatt		x	Hemicryp
	H. rugulosum Less.		x	Hemicryp
9037000	***Stoebe* L.**			
	S. vulgaris Levyns		x	Cham
9130000	***Acanthospermum* Schrank**			
	A. glabratum (D.C.) Wild #	x		Ther
9237000	***Bidens L.***			
	B. bipinnata L.#	x		Ther
	B. formosa (Bonato) Sch. Bip.#	x		Ther
	B. pilosa L.#	x		Ther
9282000	***Flaveria* Juss.**			
	F. bidentis (L.) Kuntze#	x		Ther
9291000	***Schkuhria* Roth**			
	S. pinnata (Lam.) Cabrera#	x	x	Ther
9311000	***Tagetes* L.**			
	T. minuta L.#	x	x	Ther
9356000	***Schistostephium* Less.**			
	S. crataegifolium (D.C.) Fenzl ex Harv.		x	Hemicryp
9411000	***Senecio* L.**			
	S affinis DC. (417) (416)		x	Hemicryp
	S. asperulus DC. [2] (298)	x		Hemicryp
	S. consanguineus DC. (370)	x		Ther
	S. coronatus (Thunb.) Harv. (367)		x	Hemicryp
	S. erubescens Aiton var *crepidifolius* DC. (393)	x		Hemicryp
	S. harveianus MacOwan (423)	x		Hemicryp
	S. hieracioides DC. (376)		x	Hemicryp
	S. oxyriifolius D.C.		x	Hemicryp
	S. polyodon DC. var *polyodon* (385)	x		Hemicryp
9417000	***Euryops* Cass.**			
	E. transvaalensis Klatt (305) (372)		x	Hemicryp
9425010	***Castalis* Cass.**			
	C. spectabilis (Schltr.) T. Norl. (427)		x	Hemicryp
9432030	***Haplocarpha* Less**			
	H. lyrata Harv. (369)		x	Hemicryp

Table 3 cont.

	Species	Ash	Grass	Life form
9434000	***Gazania* Gaertn.**			
	G. krebsiana Less. subsp. *serrulata* (DC.) Rössl.		x	Hemicryp
9438000	***Berkheya* Ehrh.**			
	B. setifera DC. (400)		x	Hemicryp
	B. zeyheri (Sond. & Harv.) Oliv. Hiern (401) (413)		x	Hemicryp
9462000	***Cirsium* Mill. *emend.* Scop**			
	C. vulgare (Savi) Ten.# (342)	x		Ther
9501000	***Dicoma* Cass.**			
	D. gerrardii Harv. ex F.C.Wilson		x	Hemicryp
	D. zeyheri Sond. subsp. *Zeyheri* (331)		x	Hemicryp
9528000	***Gerbera* L.**			
	G. galpinii Kla:. [2] (243)		x	Hemicryp
	G. piloselloides (L.) Cass		x	Hemicryp
	G. viridifolia (DC.) Sch. Bip. subsp. *natalensis* (Sch. Bip.) H.V. Hansen (354)		x	Hemicryp
9572000	***Hypochoeris* L.**			
	H. radicata L.# (406)	x		Hemicryp
9592000	***Taraxacum* Weber *ex* Wiggers**			
	T. officinale Weber *sens. lat.* #	x		Hemicryp
9579000	***Tragopogon* L.**			
	T. dubius Scop# (420)	x		Ther
9595000	***Sonchus* L.**			
	Sonchus sp. (380)	x		Ther
	Sonchus sp. *cf. asper* (L.) Hill subsp. *asper*# (351)	x		Ther
	S. oleraceus L.#	x		Ther
9596000	***Lactuca* L.**			
	L. capensis Thunb. (328)	x		Hemicryp

Exotic species #
Species used in rehabilitation *
1: According to Retief & Herman (1997)
2: Identified by the National Botanical Institute, Pretoria
Life forms according to Rankiaer (1934)

Cham:	Chamaephytes
Cryp:	Cryptophytes
Hemicryp:	Hemicryptophytes
Phan:	Phanerophytes
Ther:	Therophytes

Numbers in brackets are collectors numbers for Morgenthal, T.L. housed in the A.P. Goossens (PUC) Herberium

sites was considerably larger than that of the natural area studied. Seven more species occurred in the natural grassland than on the ash disposal areas. A major difference in the survival strategy of species existed in the two areas. A larger amount of species on the ash disposal areas had an annual life cycle (therophytes) and therefore survived in the form of seeds during harsh conditions, while most of the species in the natural grassland were perennial. The shoots of these perennial plants die back to ground level during the unfavourable season so that the lower part of the plant is protected by the soil and withered leaves (Raunkiaer 1934).

To make the floristic composition of the ash disposal areas more similar to the floristic composition of the natural grasslands it would be necessary to find species adapted to both areas. Higher seed input of the grass species *Eragrostis plana*, *Setaria sphacelata* var. *torta*, *Heteropogon contortus*, *Themeda triandra* and *Brachiaria serrata* would probably have to be made. The adaptability of these species to survive the adverse growth conditions on ash disposal areas is, however, not well known. Results from surveys conducted on ash disposal areas on which seeds of *Heteropogon contortus* and *Themeda triandra* were used together with other grass species indicated that these species did not colonise well.

An analysis of the floristic composition of disturbed areas may provide valuable information regarding the identification of species to be used in restoration and rehabilitation strategies. The identification of benchmarks and experimental controls to evaluate the quality may be greatly improved if the total floristic compositions of the two areas were compared beforehand. The vegetation on ash disposal areas would probably never achieve the same floristic composition and life form characteristics that prevail in the natural grassland, due to the drastic environmental differences. Multivariate analysis between the natural grassland and rehabilitated ash disposal sites showed that the difference in the species composition between the two areas were substantial (Morgenthal *et al.* 1999). Other criteria, such as life form characteristics of species, than species composition may be a solution, as indicated by Down (1973), to determine the condition and rehabilitation success of rehabilitated vegetation. The number of therophyte (annual species), which are typical of ruderal vegetation (Grime 1979), may be a good indication of the successional stage of the vegeta-

tion. The relation of r-selected (therophytes) to K-selected (Pianka 1970) species may also be a good indicator of the successional stage in the vegetation. Therophytes, therefore r-selected species, were, for example, more abundant on rehabilitated ash disposal sites than in the natural grassland.

Although both areas were dominated by species of mostly three plant families certain families, were found to be habitat specific and only occur in one of the two areas. Certain families can, therefore, already be indicators of the habitat or degree of plant community development.

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